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Using Methods of Non-linear Dynamics in Historical Social Research: Application of Chaos Theory in the Analysis of the Worker's Movement in Pre Revolutionary Russia.

*Audrey Andreev, Leonid Borodkin, Mikhail Levandovskii**

Abstract: Social conflicts often contain unpredictable peaks of activities and relatively long periods of non-stable behaviour. How could we explain such a non-linear, chaotic behaviour? What is more substantial - internal factors of these effects or external causes? Sometimes historians take into account only external factors as the main causes of the historical phenomena, though they possibly play the »trigger« role in the processes of the »social explosives«. Such questions can be asked in the investigation of the strike movement in Russia in the end of 19th and the beginning of the 20th century. One of possible ways to answer these questions is to apply the theory of non-linear systems with dynamically stochastic behaviour (or »chaos«), developed in the last decades. We used official statistics of industrial strikes in the Russian Empire during the years 1895-1908. Our research demonstrates the possible appearance of »chaos« (in mathematical sense) in the system behaviour and the existence of a rather long unstable period. To describe the development of strike movement we built the quantitative model. The system of the four non-linear ordinary differential equations was constructed after using advanced mathematical procedures to analyse the time-series. This model had a good predictor feature and for defined values of the coefficients

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demonstrated a chaotic behaviour. The research reveals the great role of the mechanism of information transfer and the significance of internal factors in the strike movement.

Modern Chaos Theory and Scientific Knowledge

Modern chaos theory as a developed gnosiological concept marked the beginning of a new scientific revolution which naturally completes the basic changes of the philosophy and methodology of knowledge deduced from new researches (especially in natural sciences) during the 20th century. Many theories and notions previously seemed beyond discussion and used as a building block of knowledge were dispelled. For example, Einstein's investigations, under some conditions, proved space and time to exhibit properties defying our common sense which not only is unable to explain them but even plagues the understanding. Several decades later the base of scientific knowledge was attacked more heavily when the quantum theory had thrown doubt on the principle of cause-effect interconnection. According to this theory founded on a great deal of experiments in the world of microphysics one can only judge the probability of some certain event and not its cause, but the probability evolves under severe physical laws which provide its calculation. Furthermore there exists a fundamental limit of accuracy inherent in the description of any physical object by trivial notions such as speed, energy and so on (Heisenberg's uncertainty relationship). It means, "object" itself ceases to have objective properties, its existence being possible because of the lack of information, and any features observed from the experiments were subjective, influenced by the observation procedure.

Nevertheless, the concept of "cause and effect" remained valid from the standpoint that the quantum theory gave a strict prediction (depending on initial conditions) on the processes where many events considered and only average quantities made sense. This aspect allowed a group of thinkers (who represent a neopositivistic approach) to emphasize such a gnosiological feature as predictability of phenomena, no matter how we could get the prediction, and our theoretical complications would appear from the inadequacy of the method applied, but not reflecting the essence of nature which remained as in the classical 18th century philosophy under the rule of general "objective" laws, not yet discovered. The contrary position was formulated by K. Popper, who drastically criticized the "objectivity" notion and denied complex phenomena especially as regarded in social science to obey any global universal laws. The discussion is yet far from completion, so different attempts inspired by the ideas of objective law searches, including history as well, occurred from time to time. That's why it is interesting to point out, that the chaos theory methodology based on a critical review of the law of universal cause-effect interconnection and the principle of predictability stands near to the ideas of Popper.

A justified presentation of gnosiological aspects of the chaos theory is given in several recent works by I. Prigogine and I. Stengers[1]. At the main center of their concept the authors put an idea of "becoming world", a creative evolution of the Universe[2] closely connected with the problems of instability and irreversibility of global processes thoroughly investigated in modem physics. This evolution won't be possible in the deterministic world of classical physics and philosophy, where, as Leibnitz stated, causes and effects uniquely determine each other so that a process directed forward into the future is as real as directed backwards to the past, for example, champagne splashes coming back into the bottle. The chaos theory now obtains the methods for going from such a deterministic world to irreversibility and appearance of "the arrow of time" through so called stochastic processes with random paths of particles and special points of bifurcation where a system really has a free alternative of further behaviour. As they say, an observed reality classified by science lies on a "narrow path" between a fully predictable universe, i.e. out of time, memory, history, and a world of pure accidents. Instead of former requirements of "scientific objectivity" we now have rather challenge for more extent ratio of science, and this affects particularly the human sciences studying culture as a domain where creative abilities of people are applied. As a response to these ideas originated from natural science an outstanding Russian culturologist Yury Lotman developed a theory of discontinued, non-progressive culture evolution which has the most informative and effective part in the unpredictable area with chaotic behaviour and broken "semiotic codes" while a new order comes into being.[3]

The general idea of "objective laws" in human sciences has appeared from the principles of classical physics, applied frequently as a rough imitation. K. Popper called that *historicism,* and claimed that because no motion existed in society, it is in any sense analogous to the motion of physical bodies. Therefore no laws of such a motion exist. What for the tendencies of social evolution calculated from statistics, they are, of course, of some mathematical value, but *tendencies are not laws,* so that each statement of them would be a unique historical assertion and not a universal law. This means no definite predictions could be derived from historical data, but only probable forecasts[4].

Thus, a scientific description of phenomena must build a research not for absolute laws, hardly present, but for all possible paths of further development.

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[1] **Prigogine, Aya / Stengers, Isabelle, 1986: Order out of Chaos: Man's new Dialog with Nature. London. Fontana Paperback. Prigogine, Ilya / Stengers, Isabelle, 1995: Time, Chaos, Quantum. New York.**

[2] **Bergson, Henry, 1911: Creative Evolution. New York, Holt. cop.**

[3] **Lotman, Yuriy, 1993: Kultura i Vzryv (Culture and Explosion). Moscow.**

[4] **Popper, Karl-Raimund, 1957: The poverty of historicism. Boston. Beacon Press.**

which can be expressed in the framework of regularities discovered with some probability. The multivariability of historical evolution is a main principle of those statements where the positivists would like to see the universal "laws of nature". Their mistake follows from such a common place that every historian can observe the only path realized and explains it in terms of causes and effects like a "prophet predicting not forward but backward" (words of F. Schlegel)[5]. But the *realization* of that path, as the chaos theory strictly demonstrates, provides a great number of situations (corresponding to instability and bifurcations of the system) principally unpredictable results, even with boundary or initial conditions known with the highest degree of accuracy, and therefore has "subjective" features. When, for the first time, physicists encountered the same situation, they formulated it in the following way: "Though during the experiments on atomic processes we deal with facts and objects as real as the other phenomena of everyday life, atoms and particles, to a certain extent, are not so real; they form the world of tendencies and probabilities rather, than facts and objects... We use the notion of probability function to describe such processes, and this notion contains an objective part of tendency calculated and a subjective part, relative to a principle lack of knowledge, describing not a unique event but a statistic ensemble of all probable events. The observation itself chooses from all variants the only one to be realized"[6].

Now one could say that it is the chaos theory that unifies different branches of science playing the role of the interdisciplinary methodology, based on the accurate mathematical researches, which is able to resolve the old theoretical complications and to provide new fruitful approaches in exploring the mechanism of "actualization of possibility". This mechanism is apparently of great importance in historical science. Every description of historical phenomena is known to be treated subjectively, but now this "subjectivity" ceases to prevent scientific knowledge and is included as a part of its construction. We have really two levels of historical research: the first, operating with concrete people with their troubles, thoughts, hopes, spiritual and cultural world; historical events as dramatic plays with a confined number of participants; life as a whole, valued owing to its varied experience, which can be brought closer to our days we call it history "alive"; and the second level of "abstract history", operating not with people but abstract notions, models, such as society, political institutions, economics, revolutions, wars (because a description of war is a model too)[7]. The general statements which seemed to be of value because of their universal character and prediction ability, belong to the abstract history and, as we now understand, have no power without drawing attention to subjective properties of individual event. As Popper claimed, the

[5] **Lotman, Yuriy: Op. cit.**

[6] **Heisenberg, Werner, 1959: Physik und Philosophie. Frankfurt a.M. Ullstein Bücher.**

[7] **Popper, K.: Op. cit.**

purpose of social theory was to build up sociological models and analyze them in terms of individuals, their relations, expectations that gave the base principle of methodological individualism. We may add that it is the subjective analysis of history "alive" that could strengthen abstract history conclusions, which are principally unable to have a character of general laws because they can't consider a free subjective choice between different ways of evolution of a system involved, performed by people and described in history "alive". With regard to this choice, the concept of "cause" or initial conditions specify no more than a diversity of paths for further development to be chosen, its result remaining out of examination with the help of those notions and thus unpredictable. The main accent removes from *"why?"* to *"how?"* questions, and the last is a problem of history "alive" . Certainly, a number of cases where the evolution could progressively go in a predictable way during some period of time should not be abandoned, but they stand up as exclusions among a great deal of unstable (explicit or hidden), unpredictable situations, extracted from historical events, like prominent deterministic theories of classical physics, and are no more than tiny islands in the ocean of systems with chaotic behaviour. It should be stressed again that a decisive indicator to distinguish systems is the presence of chaos, which can be revealed by any method available, and dramatically changes all the properties of the situation under discussion[8].

The study of labor activity provides a typical problem for an abstract history. As primary model objects abstracted from the history "alive" picture, there are the working class, labour concentration, strike readiness and so on. The resulting mathematical model gives a quantitative description of workers' activity corresponded with data observed, as well as a prediction for future behaviour. But the revealed presence of chaos in time series, relating to strike dynamics as one of the components of labour activities that has given rise to the 1905 revolutionary explosion in Russia, leads us to some corrections in the interpretation of the model. First of all, we must decisively reject the attempts of defining the causes of sharp strike increase in terms of abstract history, as they were used to be explained, for example, by talking about "crisis", because (paying no attention to certain ambiguity of this notion) even if we were able to determine all necessary "initial conditions" provided by crisis for primary model categories, we should never determine "how" the situation would go further, because in the case of chaos it depends upon the individual will of each worker, from *his* choice; so the explanation, if one cannot do without it, one should regard the behaviour of individuals, and not that of models.

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[8] **Comprehensive analysis of problems and perspectives of mathematical chaos theory applications in social sciences. See, for example: Müller-Benedict, Volker, 1996: Chaos und Selbstorganisation: Neue theoretische Ansätze in den Sozial-wissenschaften. Historical Social Research vol. 21. N. 1. pp 24—96 or Faber, Jan and Koppelaar, Henk, 1995: Chaos Theory and Social Science: A Methodological Analysis, Historical Social Research. V. 20, N. 1.**

But the abstract history analysis with the help of chaos theory, though rejecting the "cause" notion, suggests now a new powerful tool an examination of tendencies, including the diversity of evolution paths in the mathematical language of differential equations. Chaotic properties of a system provide some peculiarities like "strange attractors" to appear on its phase portrait, with a random distribution of paths on it while the main parameters, being strictly deterministic, should be measured by statistics. Some differential characteristics of these peculiarities make it possible to compare several chaotic systems, and this may lead to the discovery of more universal chaotic model classes (but not universal laws!), what could promise a further fruitful development of the chaos theory applications in the sphere of history.

Application of Chaos Theory in the Analysis of the Workers' Movement in Pre-Revolutionary Russia

The abandonment of the absolute deterministic approach to the historical studies requires the use of fundamentally new techniques in the quantitative history. One of the possible ways is to apply the theory of non-linear systems with dynamical stochastic behaviour or chaos, developed in the last decades. Non-linear modelling can also be complementary for conventional mathematical research. This paper covers the dynamics of industrial strike movement in Russia in the end of the nineteenth and the beginning of the twentieth centuries. We work with the detailed source, although this is not free from some shortcomings. We use official statistics of industrial strikes in the Russian Empire during the years of 1895 -1908[9] . Statistical issues edited by the inspector of factories of the Ministry of Finances, and then of the Ministry of Trade and Industry, V. E. Varzar contain monthly data on the number of strikes, their character, their participants and many other parameters related to most of the Russian provinces. Time series, extracted from these issues were taken in consideration by using correlation analysis by V. I. Bovykin, L. I. Borodkin and Yu. I. Kyriyanov[10]. Their attention was focused on the influence

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[9] **Varzar V. E.,1905: Statisticheskie svedeniia o stachkakh rabochikh na fabrikakh i zavodakh za desiatiletie 1895-1904 gg., St. Petersburg. Varzar, V. E., 1908: Statistika stachek na fabrikakh i zavodakh za 1905 g., St. Petersburg. Varzar V.E., 1910: Statistika stachek na fabrikakh i zavodakh za triohletie 1906-1908 gg., St. Petersburg.**

[10] **Borodkin, L. I., Bovikin, L. I., Kiryanov, Yu. I., 1986: Stachechnoe dvizhenie v Rossii v 1895-1913 gg.: struktura i sviazi s razvitiem promyshlennosti i izmeneniem ekonomicheskogo polozheniya proletariata. (Opyt korreliatsionnogo analiza.) in: Istoriia SSSR., Moscow, 1986. N.3. Borodkin, L. I., Bovikin, L. I., Kiryanov, Yu. I., 1989: Opyt primeneniia statisticheskikh metodov i EVM pri razrabotke pomesiachnykh dannykh po stachkam v Rossii v period revoliutsii 1905-1907 gg. In: Matematicheskie metody izucheniya massovykh istochnikov. Moscow. Borodkin, L.**

of economic and political factors on the dynamics of the working movement. Continuous time series were formed for the group of central and western provinces of the Russian Empire (including Poland) because the gubemias of Middle Asia, Caucasus and the part of Siberia have not been under the jurisdiction of the factory inspectorate. The source doesn't contain data about strikes in the state enterprises, and what is more important to the further construction of the model, there doesn't exist information about the small factories with less than 15 workers. The results of the approach, given below, can be used, on the one hand, for a phenomenological study of the situation, and, on the other hand, for the creation of a quantitative model with real coefficients. We implicitly presume that such a model does exist and can be expressed as a system of non-linear differential equations commonly in partial derivations. Such assumptions are fairly often and include a broad class of events[11].

Let us suppose that we use a system of n ordinary differential equations to construct a model with n independent variables. The phase space of such a system is a n-dimensional space, whose co-ordinates are the values of the variables. A point in the phase space corresponds to each moment state of the system. For Hamilton systems it is more convenient to consider 2n-dimensional phase space with n co-ordinates equivalent to the variables and n co-ordinates equivalent to their derivatives. The system dynamics can be represented by the motion of the points. The point trajectory is called a phase curve. The attractor of the system is a subset of phase space on which all solutions of the system will be closed. The stable or stationary point is the point where all time derivatives are equal to zero. In these points the system is in stable or unstable equilibrium. Stable singular points are also the attractors. Closed phase curves or limit cycles correspond to periodic motions. Stable limit cycles can also be termed as attractors. Stationary points, limit cycles and some other classes of the attractors originated in multidimensional systems are returned to as simple attractors. The available nonstationary processes result in a generation of the so-called strange attractors. Strange attractors can appear in the systems with the degree of freedom more or equal to three. Systems with strange attractors have the fractal dimension. Available fractal dimension in the system's attractor is the sign of the chaotic mode and can be found by numerical methods. In the phase space of the dynamic system we can choose a slice plane crossing the phase curves but not tangent to them. Let us consider a phase curve, crossing the surface in the points A,B,C and so on. We can enter a function transfer A to B, B to C, etc. These functions are called point mappings

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I., Kiryanov, Yu. I., 1993: Rabochee dvizhenie v Rossii v 1895-1914 gg. i faktory ego razvitiia. In: EVM i matematicheskie metody v istoricheskikh issledovaniiakh. Moscow.

[11] **See, for example: H.-O. Peitgen / H. Jürgens / D. Saupe, 1992: Chaos and fractals. New frontiers of science. Springer-Verlag.**

or the Poincaré mappings. A fixed point is the point which is transferred in itself by mapping. The fixed points in such mapping present the limit cycles. Quasiperiodic motions notated by the closed curves. These curves form w-order cycles. For example, a 3-order cycle is associated with the map f so that B=f(A), C=f(B), A=f(C). For the one-dimensional map such a cycle can be easily found. The Poincaré map taken in the definite moments gives us an opportunity to determine the motion and the scenario of the transition to chaos. One of the most common situations is the doubling of the map cycle's periods. The cycle with the period 2 arises from the fixed point and the period is doubled to 4, 8, 16... and to infinity, e.g. chaotic regime. It should be noted that in many situations the maps can be transformed to nearly one-dimensional ones.

The Non-linear Version of the Strike Dynamics in the End of the Nineteenth and the beginning of the Twentieth century

The systems governing the historical phenomena have generally an infinite phase space and all attractors can appear in them (the so-called distributed systems). Most of the conclusions have been drawn for the systems of ordinary differential equations, and are accurate for the dissipative ones. The dynamics of these systems with such attractors are similar to that of the finite systems, e.g. if we reconstruct an attractor from our data we can create a finite system of ordinary differential equations defining the process with the analysis of the attractors. The simulation model describing this system has all the merits of an analytical one[12].

The system dimension follows the number of the equations. It can be defined by the minimal length *d* sufficient for the correlation between the different intervals of the time series. These correlation point to the fact that a strange attractor appears in the «-dimensional phase space where the solutions of non-linear systems form a group of trajectories. The strange attractor consists of trajectories with typical »scattering«, so that every two points lying closely on the neighbour curves at the characteristic time T (Lyapunov time) strongly diverge and in future wouldn't have any connections. Thus we can say that the system is unstable and demonstrates a chaotic behaviour because an extremely small difference in the initial conditions leads to the complete disagreement of the final results.

The method used to define the type of the attractor is based on the so called »reconstruction of the attractor«, that was suggested by F. Takens and D. Ruelle. The fact is that a straightforward extension of this procedure allows us

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[12]Borodkin, L. I., 1997: Mathematical models of Historical Processes: From the existing to emerging in: Fiztech Journal, vol. 2, N. 1. Moscow, pp. 67-75.

to reveal the geometric structure of any underlying attractor. It has been used in such different fields as epidemiology[13], chemistry, ecology, economics and computing hydrodynamics[14]. The method has an important advantage: one needs the only rather long record of one variable (the so called reference orbit). Let us denote it *x*. An approximate phase portrait of the system x(t) in the cords (x(t), x(t+t), x(t+2t)...x(t+2Nt) can be generated by plotting x(t) vs. x(t+t), where t is the time constant lag. If N is chosen large enough such a phase portrait will have the same dynamical properties as those constructed from the independent variables following the Ruelle-Takens procedure.[15] In many important applications it is sufficient to consider 3-dimensional co-ordinate mesh.[16] In practice we have to control the appearance of the self-crossing in the reconstructed space. The choice of time lag is almost arbitrary. However, in practice there are limitations.[17] This procedure of reconstructing an attractor can be interpreted as a change of co-ordinates. For historical systems when we work in the infinite dimensional space the reconstruction amounts to a projection of the original to a finite dimensional space. By choosing the dimension of the embedding space large enough it is guaranteed that each point in the projected attractor corresponds to one and only one point in the original attractor. Thus, the reconstructed attractor is more or less a distorted copy of the original one.

The phase space is sliced by a plane transverse to the phase flow (not tangent to it and taken in a defined direction), and Poincare sections are obtained. One-dimensional (1-D) maps are constructed by plotting successive (the (i+l)-th vs. the i-th) points on the sections. We can make immediate conclusions about the system dynamics with the help of 1-D maps and the map properties are independent on the choice of the slice plane. In our case it is natural to take the time series of the number of strikers as an independent variable. (The number of strikes is approximately proportional to the number of strikers). The data analysed are shown in Figures 1 - 2 (number of strikers in different scales) and Figure 3 (number of strikes).

Firstly, it is necessary to investigate the main features of the system dynamics. For a first approximation a power spectrum is computed both for the complete time series for 1895 - 1908 and for the time series with the deleted data for the revolutionary period of January, 1905 to June, 1907. The plots of power spectra are given in Figs. 4 and 5. On these plots the ordinates are log power, i.e. the sum of the squares of the real and the imaginary parts of the fast Fourier-transform results, and the abscissas are frequencies (0 to 0.5 cycles per

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[13] **Shaffer, W. M., Kot, M., 1985: J. Theor. Biol. 1985, 112, pp. 402-427.**

[14] **See other examples in: Stewart, I., 1990: Does God play dice? Penguin Books.**

[15] **Takens, F., 1981 in: Lect. Notes in Mathematics., N.-Y., 1981, p. 366.**

[16] **Shaffer, W. M. : Op. cit. p. 408.**

[17] **Malinetskii, G. G., Potapov, A. B., 1995: Geometry of strange attractors and determination of the Lyapunov exponents from a time series. Preprint of the Institute of the applied mathematics. Moscow.**

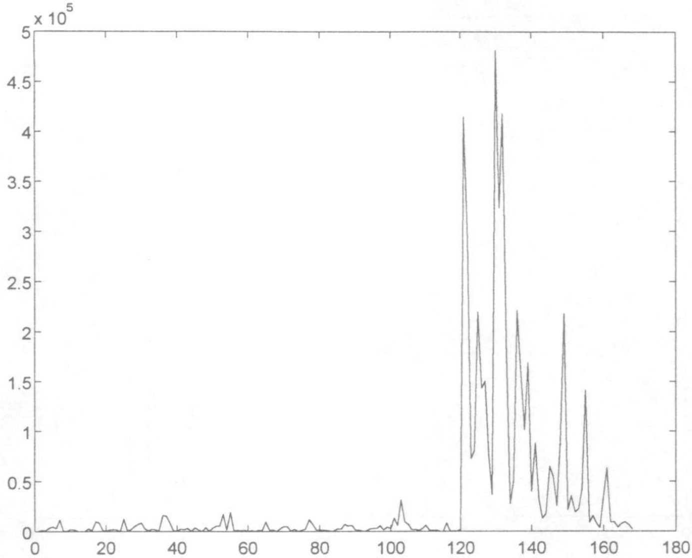

Figure 1: The number of strikers in Russia. 1895-1908.
(strikers vs. months).

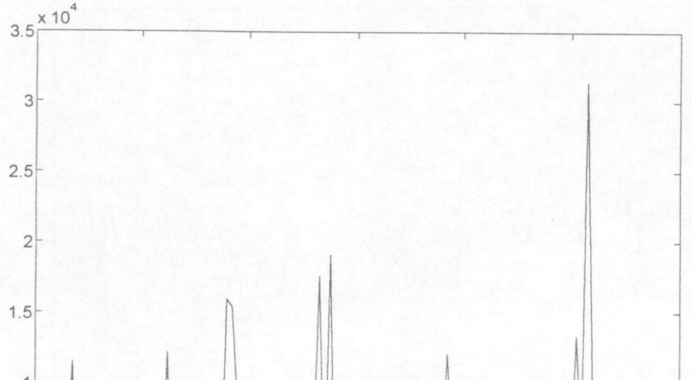

Figure 2: The number of strikers in Russia. 1895-1904.
(smaller scale, strikers vs. months).

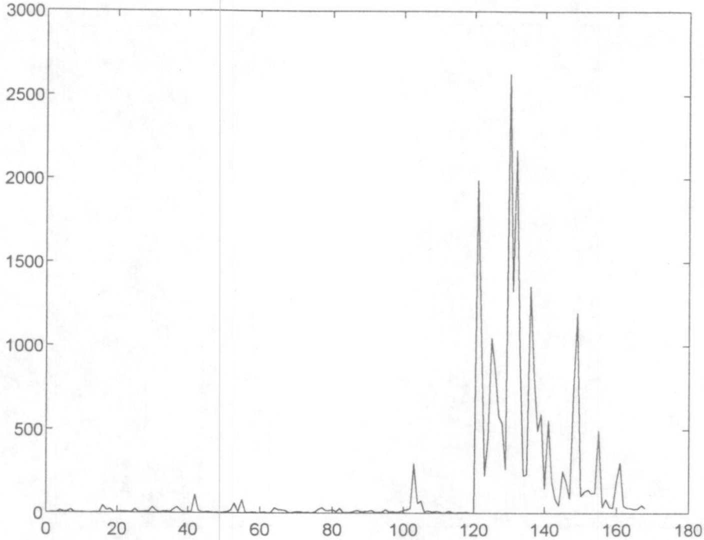

Figure 3: The number of strikes in Russia. 1895-1908.
(strikes vs. months).

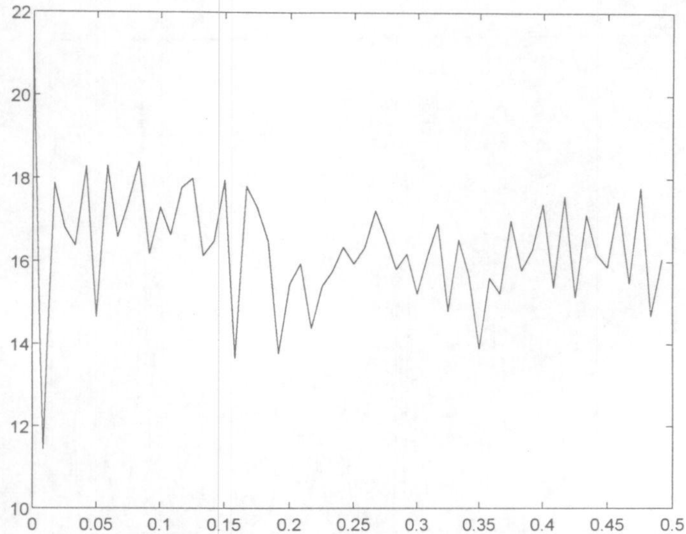

Figure 4: Power spectral density for incomplete time-series for srikers.
(log power vs. frequency).

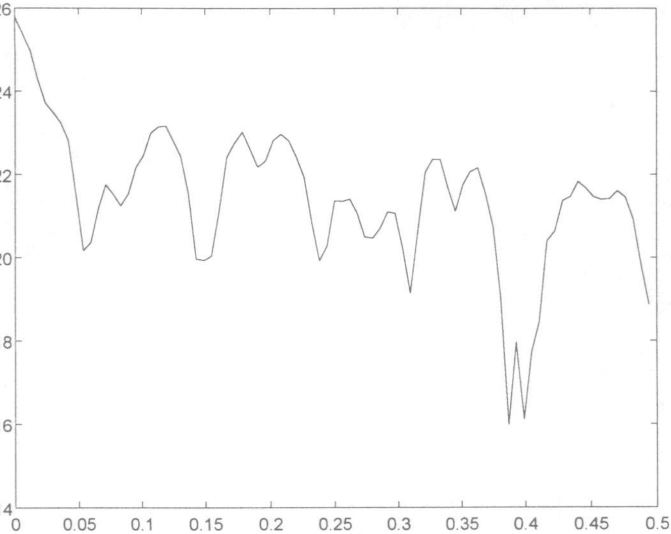

Figure 5: Power spectral density for complete time-series for srikers.
(log power vs. frequency).

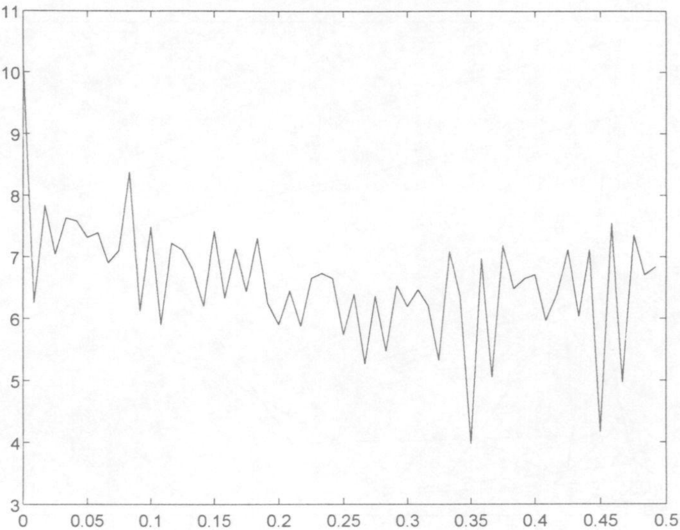

Figure 6: Power spectral density for incomplete time-series for srikes.
(log power vs. frequency).

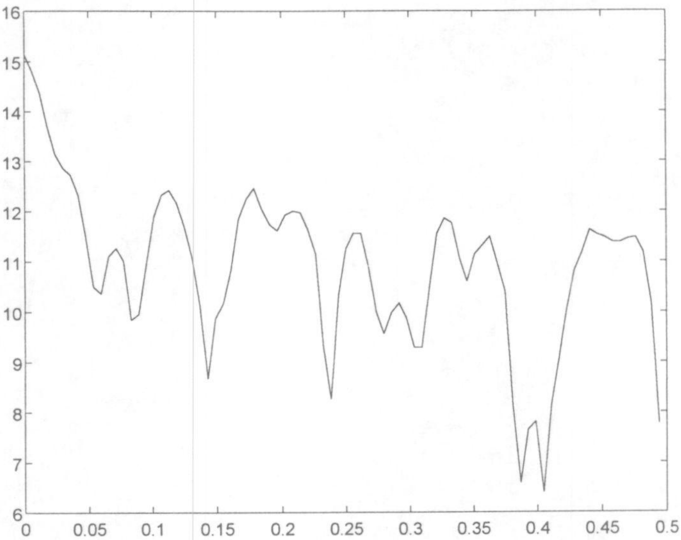

Figure 7: Power spectral density for complete time-series for srikes.
(log power vs. frequency).

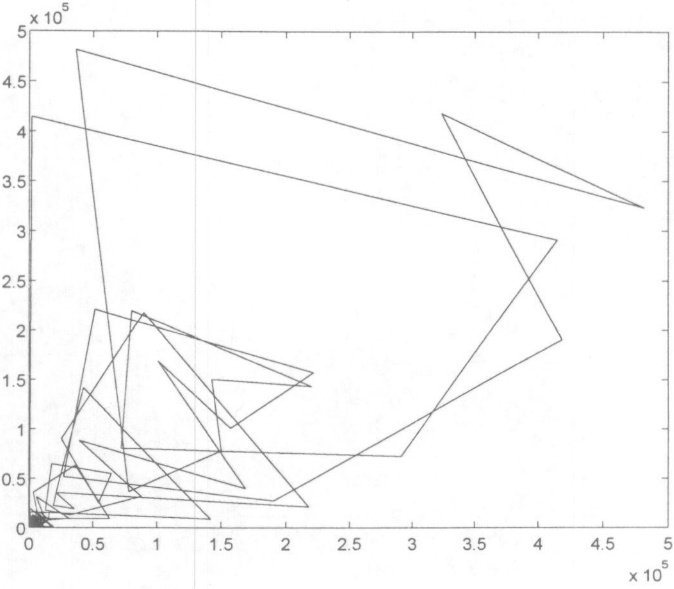

Figure 8: The plane projection for the attractor reconstruction.

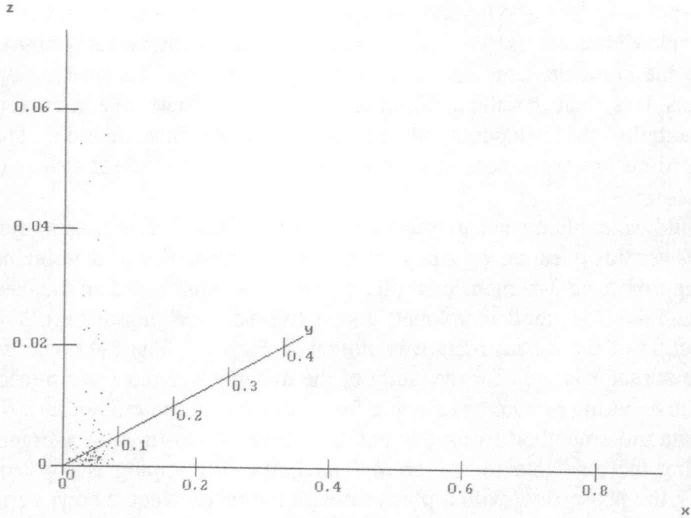

Figure 9: The 3-D reconstruction of the attractor.

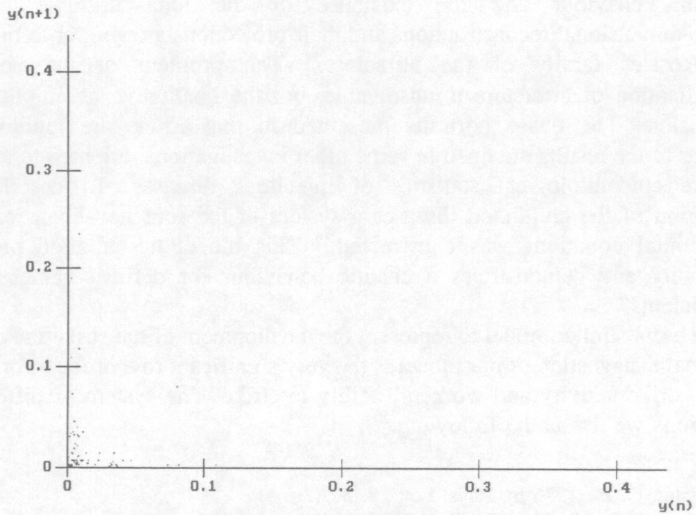

Figure 10: The Poincare mapping.

months, because of the plot symmetry). There is a high peak at a frequency corresponding to about one year's period (11.4 months precisely) for incomplete time series. This is in good agreement with Varzar's observations. As to the complete time series we see another picture - a strongly aperiodic process. It is clear that the addition of the relatively short time interval changes substantially the behaviour of the system under investigation. The same conclusions are even more in contrast to the power spectra for strikes (Figures 6-7).

Could we explain such an effect on the base of non-linear chaotic dynamics? To answer this question we study the dynamical properties of the obtained data. The approximate 3-dimensional phase portrait is constructed on the base of the Ruelle-Takens method mentioned above (we use one month lag). The plane projection of the reconstruction is plotted in Figure 8. The 3-D reconstruction of the attractor is used for the study of the dynamics of our system (see Figure 9). The resulting picture has a conic form. To prevent the influence of the noise the data are smoothed using the standard three points running average before entering the data into the program. The Poincare mapping is constructed by slicing the phase flow with a plane through the reconstructed cone vertex (see Figure 10). The points relevant to the Poincare sections are fitted using the linear regression to a line whose length is scaled on the interval [0,1]. After that procedure the length of the curve becomes a parameter to define the position of the point on the one-dimensional map. The investigation of the nearly one-dimensional map demonstrates the possible appearance of chaos in the system behaviour and the existence of the long unstable periods. Three-dimensional reconstructions and their projections are similar to those for the Rossler family of the attractors.[18] The problem of the complete classification of attractors is unsolvable, but the qualitative assumptions are admissible. The phase portraits presented in this article are topologically similar to the results obtained in some other investigations, oriented to analysis of the epidemiological statistics of infectious diseases. To describe the transition of the childhood diseases a system of the four non-linear ordinary differential equations was constructed.[19] This model has a good predictor capability and demonstrates a chaotic behaviour for defined values of the coefficients.

We use a similar model to represent the development of the strike movement. The main suggestion of our model is the very significant role of the information about strike activity and workers' ability to strike. The system of differential equations we use is the following:[20]

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[18] **Rossler, O. E., 1976 in: Phys. Lett., v. 57A.**

[19] **Anderson, R. M., May, R. M., 1982 in: Science, v. 215.**

[20] **This system is used also in historical demography for example for studing the epidemics in 18th century. See: Duncan, S. R. / Scott, Susan / Duncan, C. R., 1994 in: Journal of Interdisciplinary History. V.XXV: 2. pp. 255-271.**

$$dX/dt=m(N - X) - bXZ$$
$$dY/dt=bXZ - (m + a)Y$$
$$dZ/dt=aY - (m + g)Z$$
$$dW/dt=gZ - mW$$

In this system N is the total number of the workers in the selected gubernia, X is the number of the workers which can be determined as susceptible to striking activities, i.e. the workers who are not yet able to take part in the strike, Y is the number of workers who have argued to take part in the strike, but are not the active propagandists, Z is the number of the professional propagandists and the socially active workers, W is the number of workers who refuse to take part in the strikes more than once. In the first approximation N can be assumed constant and normalised to 1, in this case the variables are expressed as proportions with X+Y+Z+W=l. The sum of their derivatives is zero, so the X+Y+Z+W is a constant during all the periods of integration.
The average time the worker spends at the selected enterprise is given by *llm* (it corresponds to the life expectancy used in historical demography), *lla* and *llg* are, respectively, the proportion between active and passive participants of the labour unrests and the time interval of the »one bit information effectiveness. The estimated values of the mentioned parameters for various locales can be obtained directly from census data and from special literature (in the case of *m* and *a)* or are evaluated from the simple assumptions (in the case of *g)*. However, the contact rate *b* should be estimated indirectly from the investigation of the average level of the strike activity.

If the coefficients *m, a, g,* and *b* are held constant, the solution of our system is a weakly damped oscillation. This is inconsistent neither with real observations, nor with the attributes of chaotic dynamics. The modification of the coefficient *b* allows us to correct the model. As early as in the beginning of the 20th century V. E. Varzar pointed out the seasonal nature of the workers' activity.[21] To take into account the periodical activity we changed the expression *b=const* to the *b(t)=d(l+c*cos2pt),* where *d* is the average transition coefficient and *c* the seasonal term.

Setting after the computer experiments m=0.02, a=2.86, g=8.37 and d=120 (all the coefficients are measured in 1/month) the solution of the system shows the simple annual cycle for the values of *c* between 0 and 0.1; for 0.1(c(0.2 the transition to the two-year cycle, then the sequence of the period doubling bifurcations and after all in the vicinity of c=0.25 the transition to the stochastic dynamics. The attractor derived from the solution of the system is shown in Figure 11. It is similar to the one reconstructed above. Taking into account the natural discreteness and rarity of the historical data we have a good agreement between them.

[21] **Varzar, V. E., 1905. Op. cit. p. 38.**

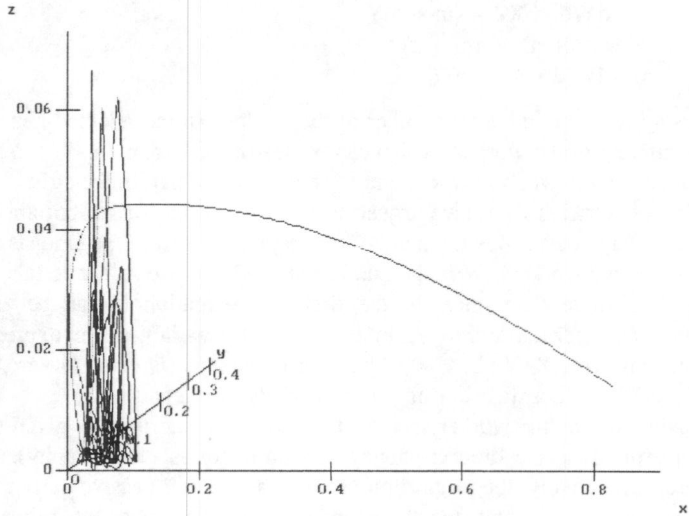

Figure 11: The attractor of the system's solution.

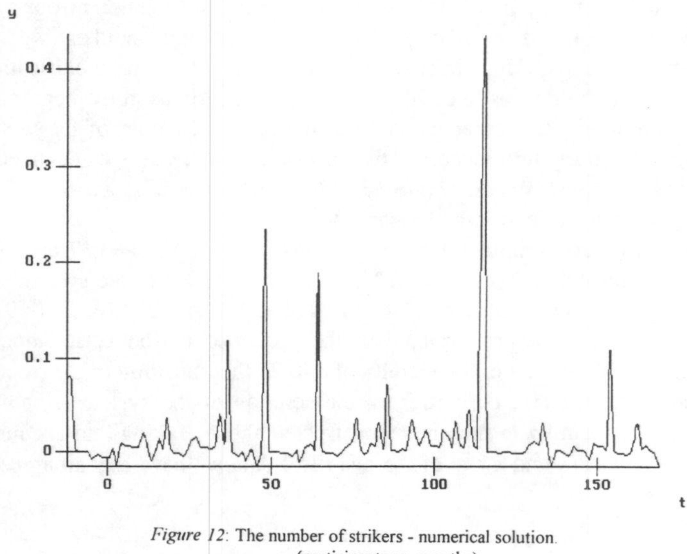

Figure 12: The number of strikers - numerical solution.
(participants vs. months)

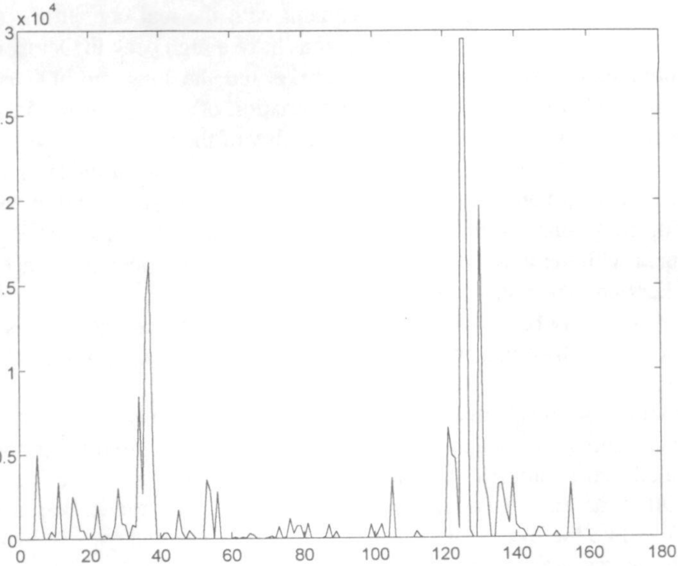

Figure 13: The official data for Vladimir province. 1895-1908 (strikers vs. months).

***Figure 13* The official data for Vladimir province 1895-1908 (strikers vs months)**

The simulated output of the number of strikers is demonstrating a chaotic behaviour. The model has been adopted for the Vladimir gubernia (one of the most developed industrial provinces in Russia). We use the data from the limited territorial unit to provide a correct approach for the study of the mechanisms for the information dissemination (under the assumption that the main channel of the information transition are the person-to-person contacts between the workers). Another condition we need for the construction of the model is a constant number of workers. In the Vladimir gubernia industry was developing intensively during the previous decades of the nineteenth century; during the period under consideration there was no significant acceleration. The strike movement had formed in the previous years too. So it is convenient to establish the initial conditions. A situation like this corresponds to the phenomena of the deterministic chaos. The system of the differential equations was solved with the initial conditions for the strike movement in Vladimir gubernia.[22] The results are shown in Figure 12. The real data are plotted to be compared in Figure 13. To create a local cronicle of this separate province we use officially printed material[23], recent investigations[24] and archive funds.[25] The

[22] **Kresina, L. M., 1959: Rabochee dvizhenie vo Vladimirskoi gubernii v kontse XIX - nachale XX veka. Vladimir.**

[23] **Svody otchiotov fabrichnykh inspektorov. Spb. 1901-1914.**

[24] **Kresina, L. M.: op. cit. The application. Khronika stachechnogo dvizheniia v Rossii. 1895-1896. Ed. Yu. I. Kiryanov. Moscow, 1995.**

[25] **Russian State Historical Archive (RGIA) fund N. 23. inv. 17. file 326.**

simulated dynamics are in good agreement with the real one (in the sense of general dynamical tendencies). Both graphs have a high peak in October 1905 - the month of the all-Russia political strike and the long unstable period in 1905-1907. This is only the first approximation of the model not taking into account the significant changes in the mentality of the workers in the beginning of the twentieth century. The overestimated values of the simulated number of strikers can be explained by the shortcomings of the sources[26] and the necessity of taking into consideration smaller territorial units. This research is in good agreement with the thesis of high rates of correlation between the concentration of wo±ers and their strike activity.[27]

The results may be treated as basis to interpret the dynamics of the strikes as an effect of »self-organisation« of industrial workers (in terms of the chaos theory).

The »internal« mechanism of the working movement seems to offer a rather more substantial explanation than external causes can provide. It should be mentioned that simulated dynamics (Figure 12) reproduce a great peak in the year 1905 (the first Russian revolution), although the model has no »input variables« like the events of January, 1905 (»bloody Sunday« of January, 9).

With our research we mainly aim to building a "bridge" between empirical social observations and sophisticated mathematical models of chaos. More than some other authors[28] we are optimistic in the estimation of the perspectives of chaos theory applications in historical social research.

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[26] **We mentioned that the sources were incomplete. For further detailes see: Kiryanov Yu.I., 1986: Svody otchiotov fabrichnykh inspektorov i drugie pravitel'stvennye statisicheskie materialy kak istochnik izucheniya stachechnogo dvizheniya v Rossii v 1895-1914 gg. In: Statistika stachek v Rossii i v drugjkh industrial'nykh stranakh Evropy i SShA. Moscow, pp. 7-36.**

[27] **Haimson, L. / Petrusha, R., 1985: Opyt matematiko-statisticheskogo issledovaniia dannykh Svodov otchiotov fabrichnykh inspectorov o stachkakh rabochikh v Rossii v 1912-1914 gg. In: Matematicheskie metody i EVM v istoricheskikh issledovaniiakh. Moscow.**

[28] **Faber, Jan / Koppelaar, Henk, 1995: Chaos Theory and Social Science: A Methodological Analysis. In: Historical Social Research. V. 20, N. 1, pp. 70-82.**

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